ARL-TR-7241 ● MAR 2015

US Army Research Laboratory

Effects of Physical Impairment on Grenade Throwing and Weapon Loading Tasks

by Jennifer C Swoboda, William Harper, Frank Morelli, and Patrick Wiley

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED (From - To)**
March 2015	Final	May 2013–August 2014

4. TITLE AND SUBTITLE

Effects of Physical Impairment on Grenade Throwing and Weapon Loading Tasks

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Jennifer C Swoboda, William Harper, Frank Morelli, and Patrick Wiley

5d. PROJECT NUMBER

ARL 12-050

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

US Army Research Laboratory
ATTN: RDRL-HRS-B
Aberdeen Proving Ground, MD 21005-5425

8. PERFORMING ORGANIZATION REPORT NUMBER

ARL-TR-7241

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Physical impairment of a Soldier during a mission will inevitably change the Soldier’s ability to perform various mission-essential tasks. This study examined the effects of an artificially impaired hand and arm on grenade throwing and weapon loading performance. The grenade task examined distance and accuracy while throwing a grenade from the kneeling, standing, and supine positions, with and without physical impairment. The weapon loading task examined time to change a magazine on an already loaded weapon as well as loading an unloaded weapon under conditions with and without physical impairment. The grenade throwing distance data revealed (for each of the throwing postures) a significant main effect for the physical impairment condition ($p < 0.01$, differences of up to 46 inches). There were no significant main effects or interactions of the physical impairment condition relative to mean accuracy in any of the throwing conditions. Also, main effects for physical impairment were found for mean times to complete individual subtasks in throwing the grenade (i.e., pull grenade from pouch, pull pin, and throw grenade). In both weapon loading tasks, a main effect of physical impairment was revealed ($p < 0.01$). The results of this study will be used to verify and validate capability requirements used in human performance modeling for grenade throws and weapon loading under conditions of physical impairment.

15. SUBJECT TERMS

physical impairment, shooting performance, grenade throw, capability degradation, ORCA

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Jennifer C Swoboda
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**	UU	56	**19b. TELEPHONE NUMBER (Include area code)**
Unclassified	Unclassified	Unclassified			410-278-5948

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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Acknowledgments

We wish to thank the Soldiers from the US Army Research Laboratory (ARL) and the Army Evaluation Center for their participation in this study. We also wish to thank the following personnel from ARL's Human Research and Engineering Directorate, Dismounted Warrior Branch, Warrior Performance Team: Sam Ortega and Patty Burcham for providing data collection support. In addition, we would like to thank Ron Carty for providing photography and videography support.

1. Introduction

The US Army has funded a large-scale program, Joint Trauma Analysis and Prevention of Injury in Combat (JTAPIC), whose purpose is to collect, integrate, and analyze operational and injury data. The main mission of the JTAPIC program is to 1) conduct rapid, scientific- and medical-based analyses of injuries sustained in combat, 2) evaluate the effectiveness of personal protective equipment and vehicle crew protection systems, and 3) translate the findings into guidance for system developers to guide improvements that alter the performance envelopes of protection systems. Its goal is to improve the Army's understanding of vulnerabilities to threats and enable the development of improved tactics, techniques, and procedures and materiel solutions to prevent or mitigate traumatic injuries.

In support of the JTAPIC program, tasks need to be evaluated to verify and validate (V&V) task-based elemental capabilities required for the Operational Requirement-based Casualty Assessment (ORCA) model. ORCA is the primary model used across the triservice agencies for personnel survivability, vulnerability, and lethality. One of the improvements to this model is to understand the performance of injured Soldiers. When predicting incapacitation or modeling Soldier performance, ORCA compares the remaining Warfighter capabilities after an injury with the minimum capabilities required to perform the military task. The model determines whether or not the Soldier can perform the task.

ORCA includes a library of 50+ operational requirements representing combat occupations across the services. Operational requirements are created by decomposing standard military jobs into task and task elements to understand what Soldiers are required to do in a given tactical situation. The ability of an individual to perform any task depends upon a number of elemental human capabilities. High-priority tasks are identified by subject matter experts and approved by the Army Infantry Center. These high-priority tasks are the focus of research on the effect of impairment on performance.

A prior study evaluated a high-priority task—shooting performance—while under simulated physical impairment (Swoboda et al. 2012). In this study, participants performed the shooting task while under simulated impairment of their dominant or nondominant hand or eye. Two additional high-priority tasks of interest are the grenade throw and weapon loading. A literature review found there were no examinations of hand or arm impairment on either of these tasks. These tasks were broken down into elemental steps to capture timing data as well as the ability to perform under impaired conditions.

We measured the ability to perform tasks using human factors methods that simulated elemental capability degradation of arm and hand use. Volunteers were evaluated on the performance on 2 tasks: a grenade throw task and a weapon loading task, both in impaired and unimpaired conditions. These data will serve to V&V the elemental capability requirements for the grenade throw and weapon loading tasks and the effect of arm and hand impairment.

The goal of this study was to characterize task performance (grenade throw and weapon loading) during simulated impaired hand and arm conditions. The results of this study will contribute to updates in task descriptions and capability scales used in human performance modeling for task-based impairment.

2. Synopsis

Physical impairment of a Soldier during a mission will inevitably change the Soldier's ability to perform various mission-essential tasks. This study examined the effects of an artificially impaired hand and arm on grenade throwing and weapon loading performance. These physical impairment scenarios simulate when a Soldier is injured in combat but is still required to complete the mission. The ability to perform the grenade throw and the weapon loading task with artificially restricted hand use or restricted arm use simulating injury effects was evaluated. The grenade task examined distance and accuracy while throwing a grenade from the kneeling, standing and supine positions, with and without physical impairment. The weapon loading task examined time to change a magazine on an already loaded weapon, as well as loading an unloaded weapon, under conditions with and without physical impairment. The results of this study will be used to V&V capability requirements used in human performance modeling for grenade throws and weapon loading under conditions of physical impairment.

3. Participants

Ten Soldier volunteers from both the US Army Research Laboratory (ARL) and the Army Evaluation Center participated in this study. Since this was requested to be a quick turnaround project, Soldiers in the local area were recruited. Although this is a relatively small sample size, similar research studies (with smaller expected effect size than the current study) have revealed significant differences using this same sample size. Participants were not required to have any specific military occupational specialty.

3.1 Pretest Orientation and Volunteer Agreement

Participants were given an orientation on the study's purpose and the details of their participation. They were briefed on the experimental objectives and procedures, and told how results would be used and what benefits the military could expect from this investigation. Any questions the participants had regarding the study were answered by the experimenter. Test participants were informed that they could withdraw from participation at any time without prejudice. Participants were also asked for permission to photograph or videotape their experimental sessions to document task performance under impaired conditions.

3.2 Demographics and Visual Acuity

Each participant provided their personal demographic information using the demographic questionnaire (Appendix A). Participants ranged in age from 27 to 44 years. All experimental participants were Soldiers currently in the US Army. Military experience ranged from 9 to 20 years. All participants were male and all had qualified within the previous 5 years using the M4 carbine. No participants reported difficulty in seeing objects during the day. One of the 10 participants was left-handed, one reported being ambidextrous, and one expressed cross dominance.

4. Objectives

The objectives of this study were the following:

- Quantify the effect that a simulated impaired hand (dominant and nondominant) had on an individual's ability to perform a grenade throw.
- Quantify the effect that a simulated impaired arm (dominant and nondominant) had on an individual's ability to perform a grenade throw.
- Quantify the effect that a simulated impaired hand (dominant and nondominant) had on an individual's ability to load a weapon (magazine into an M4).
- Quantify the effect that a simulated impaired arm (dominant and nondominant) had on an individual's ability to load a weapon (magazine into an M4).

5. Apparatus

5.1 Soldier Performance and Equipment Advanced Research (SPEAR) Facility

The SPEAR Facility is designed to allow researchers at ARL's Human Research and Engineering Directorate (HRED) to impose and measure the effects of physical and cognitive stress on Soldier performance.

5.2 Grenade Throw

The grenade throwing location was an area marked with a throwing line behind which the participant stands, kneels, or lies supine. Two distances were marked with a pole for aiming during the accuracy throw portion of the study. One pole was placed 40 ft beyond the start line. This aiming point was used when throwing from the supine position. Another pole was placed at 60 ft, used as the aiming point from the standing and kneeling positions (Fig. 1). Participants were required to kneel, stand, or lie supine behind the throwing line and throw an inert grenade for accuracy and distance. Distance was measured from the throwing line to the resting point of the grenade, and distance was measured from the aiming pole, depending on throwing posture, to the resting point of the grenade.

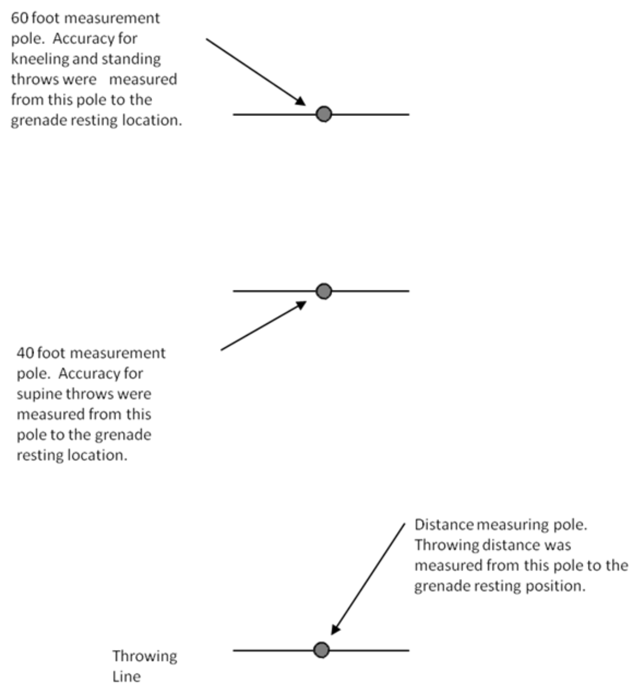


Fig. 1 Grenade throw layout

5.3 Weapons

The M4/M4A1 5.56-mm carbine (Fig. 2) is a lightweight, gas-operated, air-cooled, magazine-fed, selective-rate, shoulder-fired weapon with a collapsible polymer butt stock. A shortened variant of the M16A2 rifle, the M4 carbine is equipped with a shorter barrel, collapsible stock, and optional accessory rails. It weighs 7.5 lb configured with a 30-round magazine and is 33 inches long with the stock extended and 29.75 inches with the stock retracted. This weapon was used for the weapon loading portion of the study. Thirty-round magazines loaded with blank inert ammunition were used for this study.

Fig. 2 M4 carbine

5.4 Practice Grenade

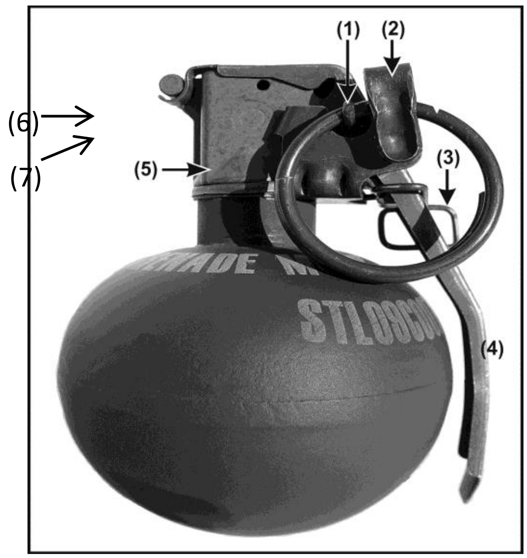
A fragmentation hand grenade has a safety lever (known colloquially as the "spoon"), a pull ring and pull pin assembly, and a safety clip (if equipped) that prevents the lever from being released (Fig. 3). The grenade weighs a total of 14 oz and is 3.53 inches long and 2.5 inches wide.

To use a grenade, the right-handed Soldier grips it with the throwing hand, ensuring that the safety lever is between the first and second joint of the thumb because releasing the lever could cause the grenade to start the pyrotechnic fuze delay. Left-handed Soldiers should invert the grenade, so the thumb is still the digit that holds the safety lever. The Soldier then inserts the index or middle finger into the pull ring of the nonthrowing hand and removes the ring using a twisting and pulling motion, ensuring to pull the safety pin assembly straight out of the grenade fuze. The grenade is then thrown toward the target. An overhand throw is recommended but may not be suitable for every combat situation. Soldiers are trained to throw grenades in standing, prone-to-standing, kneeling, prone-to-kneeling, and alternate prone positions while employing the grenade using an overhand throw. Once the

grenade is employed, the thrower will seek cover or drop to the prone position until the grenade detonates.

Once the Soldier throws the grenade, the striker rotates on its axis and strikes the primer, starting the pyrotechnic delay fuze. The fuze burns down to the detonator, which detonates the main charge. The M67 fragmentation grenade has a 4.0- to 5.5-s delay.

For the purposes of this study, a practice grenade was used, with factory-set pull pins to ensure proper pull force.



1. Pull ring and Safety pin (Pull Pin) assembly
2. Confidence Clip
3. Safety Clip
4. Safety Lever
5. Fuze
6. Fuze Lug
7. Safety Lever Hinge Ears

Fig. 3 M67 Fragmentation grenade with confidence clip

6. Experimental Design

6.1 Experimental Conditions

For both tasks, grenade throw and weapon loading, there were 5 conditions. Four involved some degree of simulated physical impairment, with one baseline included for comparison. The following conditions were tested in this study:

1) Baseline: no simulated impairment.
2) Simulated impairment of dominant hand.
3) Simulated impairment of nondominant hand.
4) Simulated impairment of dominant arm.
5) Simulated impairment of nondominant arm.

For the grenade throw portion of the study, the participant's position was also a factor. The grenade was thrown from each position: kneeling, standing, and supine.

For the grenade throw portion of the study, independent variables included impairment condition and throwing position as shown in Table 1. For the weapon loading portion of the study, the independent variables were impairment condition and starting with a loaded or unloaded weapon, as shown in Table 2.

Table 1 Independent variables and tasks for grenade throw

Positions	Impairment Conditions	Tasks
Kneeling	· Baseline (no impairment) · Dominant hand impairment · Nondominant hand impairment · Dominant arm impairment · Nondominant arm impairment	· Pull grenade from pouch · Pull pin from grenade · Throw grenade
Standing	· Baseline (no impairment) · Dominant hand impairment · Nondominant hand impairment · Dominant arm impairment · Nondominant arm impairment	· Pull grenade from pouch · Pull pin from grenade · Throw grenade
Supine	· Baseline (no impairment) · Dominant hand impairment · Nondominant hand impairment · Dominant arm impairment · Nondominant arm impairment	· Pull grenade from pouch · Pull pin from grenade · Throw grenade

Table 2 Independent variables and tasks for weapon loading

Impairment Conditions	Tasks Starting with Unloaded Weapon	Tasks Starting with Loaded Weapon
· Baseline (no impairment)	· Load a magazine	· Drop magazine
· Dominant hand impairment	· Release the bolt	· Get new magazine
· Nondominant hand impairment	· Aim and pull trigger	· Load new magazine
· Dominant arm impairment		· Release the bolt
· Nondominant arm impairment		· Aim and pull trigger

6.2 Training and Testing Sequence

Participants completed the grenade throw over the course of one day. Following pretest orientation, participants were directed to either the grenade throw area or the weapon loading area. The grenade throw area was marked with a throwing line behind which the participant stood, kneeled, or lay supine. Two distances were marked with a pole for aiming during the accuracy throw portion of the study. One pole was placed 40 ft beyond the start line. This aiming point was only used when throwing from the supine position. Another pole was placed at 60 ft and used as the aiming point for the standing and kneeling positions. Participants were required to kneel, stand, or lie supine behind the throwing line and throw an inert grenade for accuracy and distance. Each participant made 3 practice throws from each position and with each hand, without impairment. For the weapon loading and reloading task, each participant was given 3 practice trials starting with a loaded weapon and 3 practice trials starting with an unloaded weapon. After completion of either the grenade throw or the weapon loading and reloading task, each participant proceeded task that had not yet been completed.

After practice trials for each task, the participants began the experimentation. Half of the participants started with the grenade throw task and the other half started with the weapon loading and reloading task. The participant's order of impairment was based on Table 3. Both tasks followed the same order of impairment. Hand impairment was accomplished by having either the participant's dominant or nondominant hand wrapped and immobilized in a fist position so that fingers and thumbs could not be used for grenade or weapon manipulation. The participants were instructed that they could not use the sides of the hand or knuckles for manipulation. This prevented the thrower from using his hand for manipulation of the grenade or weapon. Full arm impairment was accomplished by asking the participant to allow the impaired arm to hang loosely by their side. They were asked to refrain from using their impaired arm for any part of the task.

Table 3 Order of impairment for each test participant

Participant	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5
1	A	B	E	C	D
2	B	C	A	D	E
3	C	D	B	E	A
4	D	E	C	A	B
5	E	A	D	C	B
6	D	C	E	B	A
7	E	D	A	C	B
8	A	E	B	D	C
9	A	B	E	C	D
10	B	C	A	D	E

A = Baseline
B = Hand, dominant
C = Hand, nondominant
D = Arm, dominant
E = Arm, nondominant

Each participant completed a total of 18 practice throws and 60 experimental throws. For each condition, each participant performed 2 throws for distance and 2 throws for accuracy at each posture. For the distance trials, participants were asked to throw the grenade as far as possible from kneeling, standing, and supine positions with their bodies perpendicular to the throwing direction (Fig. 4). When kneeling, one knee remained on the ground. For the accuracy trials, participants were required to kneel, stand, and lie supine behind the starting line and throw an inert grenade as close as they could to a pole set at a certain distance. For both the distance and accuracy trials, participants were instructed to pull the grenade from the pouch, pull the pin, and then throw. Each part of the task was timed independently and recorded.

Fig. 4 Grenade throw task from kneeling position with nondominant arm impairment (left) and pull-pin task from supine position with nondominant hand impairment (right)

After completion of the grenade throw, each participant proceeded to the weapon loading task. The participant was given 3 practice trials for each part of this task. The task was broken down into 2 timed parts. In the first part, the Soldier stood with a loaded weapon with the bolt locked to the rear and weapon on semiautomatic, dropped the magazine, got a new magazine from the ammo pouch, loaded the magazine into the weapon, pushed the bolt release, aimed, and pulled the trigger. The second part of the task required the participant to pick up an unloaded weapon (on safe and bolt forward), load a magazine from the ammo pouch, chamber a round, switch the selector from safe to semiautomatic, aim, and pull the trigger. Each of these parts of the task were timed independently and recorded. Dummy (inert) rounds were used for all tasks (Fig. 5).

Fig. 5 Weapon loading task with dominant arm impairment

The participants followed the order presented in Table 3. Participants were given a rest period between experimental conditions. After each participant completed the grenade throw and weapon loading for a condition, they completed a questionnaire (Appendixes B and C). Volunteers participated in the study during daylight hours from approximately 0800 to 1130. Data collection took place over several days due to Soldier availability.

7. Independent Variables

The independent variables for this study were the following:

- Grenade throw task
    - Simulated impairment: baseline (no impairment), dominant hand, nondominant hand, dominant arm, nondominant arm
    - Position: standing, kneeling, and supine
- Weapon loading
    - Simulated impairment: baseline (no impairment), dominant hand, nondominant hand, dominant arm, nondominant arm
    - Weapon start point: loaded, unloaded

8. Dependent Variables

The dependent variables for this study were the following:

- Grenade throw task
    - Throwing accuracy: distance from aiming pole
    - Throwing distance: distance from throwing position
    - Task time between each task: pull the grenade from the pouch, pull the pin, and then throw
- Weapon loading
    - Time to load with loaded weapon
    - Time to load with unloaded weapon

9. Data Analysis

The data for the grenade throw and the weapon loading study were analyzed similarly but separately. The data for the standing, kneeling, and supine portions of the grenade throw portion of the study were analyzed separately since these tasks were markedly different. Descriptive statistics on the dependent measures of throwing accuracy, throwing distance, and task time and loading time were calculated first.

For the grenade throw data, a 5 (physical impairment) × 3 (body position), within-subjects analysis of variance (ANOVA) was conducted on the dependent measures of throwing accuracy, throwing distance, and task time. Because of the large number of planned ANOVAs, the experiment-wise alpha level was set at 0.01. If significant main effects were observed, Tukey' HSD (honestly significant difference) post hoc tests were used to determine which conditions were significantly different.

For the weapon loading data, a 5 (physical impairment) × 2 (weapon start point), within-subjects ANOVA was conducted on the dependent measure of loading time. If significant main effects were observed, Tukey' HSD post hoc tests were used to determine which of 5 comparisons of interest were significantly different. To account for the impairment comparisons with an overall probability of 0.05, each individual comparison needed to achieve significance of 0.05/5, or $p \leq 0.01$. Bonferroni's correction was applied to achieve this result. Although false positives are still possible after this correction, it is necessary to accept these to identify the general effect that impairment has on performance given the small number of participants.

Post-experiment questionnaires were given after the completion of each impairment condition for the grenade throw and weapon loading tasks. The data was analyzed by averaging the means across participants for each of the questions.

10. Results

10.1 Grenade Throw Performance Data

10.1.1 The Effect of Physical Impairment on Grenade Throw Distance Performance

For the throwing distance data, physical impairment from the standing position ($F[4, 95], = 17.65$, $p = 0.0$) was found to have a significant main effect. Impairment of the dominant hand or arm exhibited the shortest throwing distance (Fig. 6). Tukey' HSD post hoc analyses showed that there was a significant difference in distance thrown between the baseline and the dominant hand and dominant arm conditions. The dominant arm condition also showed significant differences in distance thrown with nondominant hand and nondominant arm conditions. In addition, the nondominant arm condition was significantly different from the dominant hand and dominant arm conditions. In addition to the baseline, the dominant hand condition was significantly different from the nondominant arm and

nondominant hand conditions. Lastly, the nondominant hand condition was significantly different from the dominant arm and dominant hand conditions.

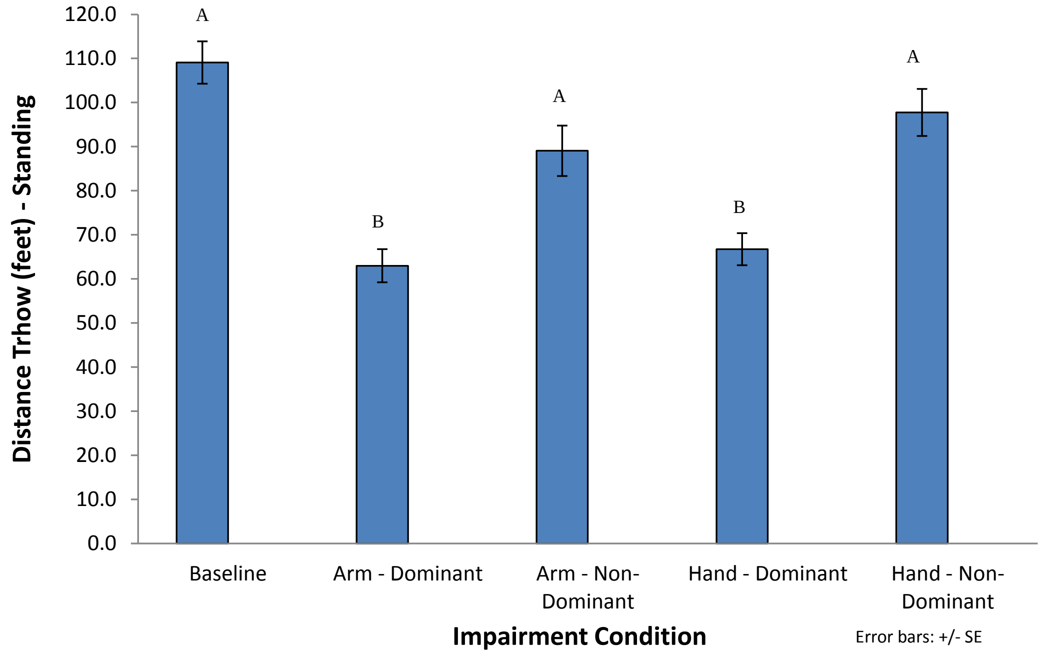


Fig. 6 The effect of physical impairment on mean grenade throw distance from the standing position. Like letters indicate that there is no significant difference.

For the throwing distance data, physical impairment from the kneeling position (F[4,95], = 12.43, p = 0.0) was found to have a significant main effect. Tukey' post hoc analysis showed a significant difference between the baseline condition and the dominant hand and dominant arm conditions. The nondominant hand condition revealed a significant difference with the dominant hand and dominant arm conditions. Similar to the standing position, impairment of the dominant hand or arm exhibited the shortest throwing distance (Fig. 7). When a participant's dominant side was impaired and he was required to switch to the nondominant side to perform the task, the distance thrown was significantly shorter.

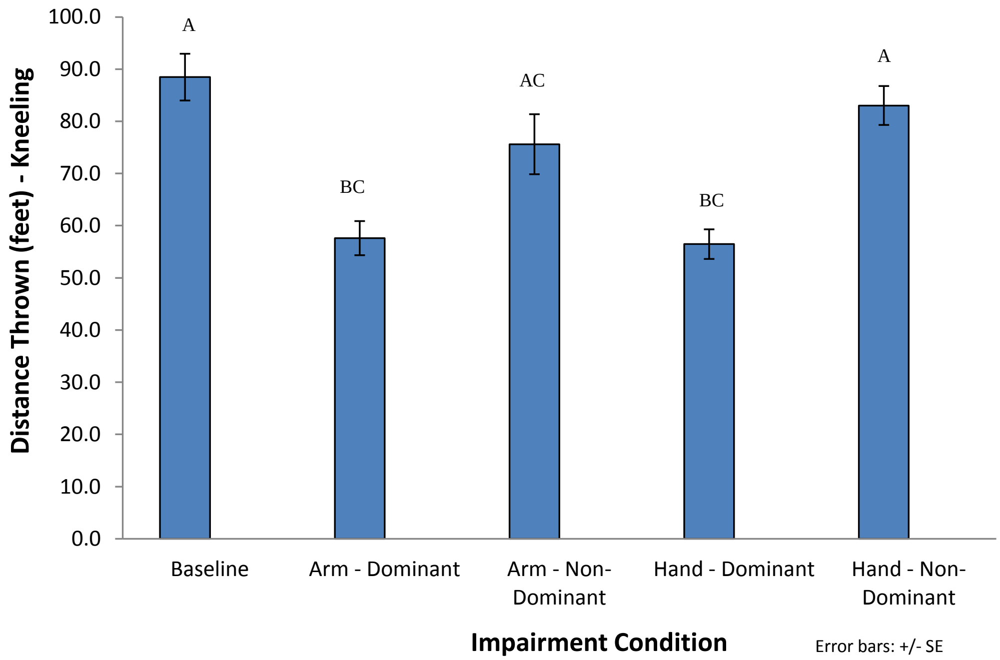


Fig. 7 The effect of physical impairment on mean grenade throw distance from the kneeling position. Like letters indicate that there is no significant difference.

In the supine position, physical impairment was also found to have a significant main effect on the throwing distance data ($F[4,95], = 7.55$, $p = 0.0$), as was the same for the standing and kneeling positions. The throwing distance in the supine condition was shortest for the dominant hand or dominant arm condition (Fig. 8). Tukey' HSD post hoc analysis showed that there were significant differences between only a few conditions. The baseline condition threw significantly farther than the dominant hand or the dominant arm condition. Impairment of the dominant arm also exhibited significantly shorter distance thrown compared with impairment of the nondominant arm.

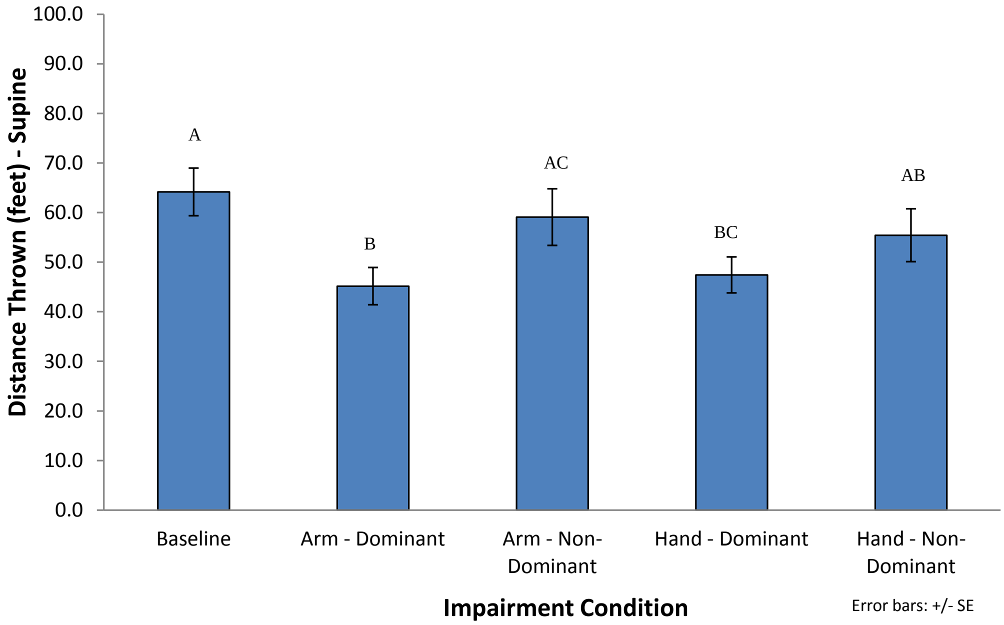


Fig. 8 The effect of physical impairment on mean grenade throw distance from the supine position. Like letters indicate that there is no significant difference.

10.1.2 The Effect of Physical Impairment on Grenade Throw Accuracy Performance

There were no significant main effects or interactions of physical impairment condition relative to mean accuracy in any of the throwing conditions. Participants were instructed to throw the grenade as accurately as possible toward one of the designated pins, depending on the posture. The pin for kneeling and standing postures was positioned 60 ft from the throwing line. The pin for the supine posture was positioned 40 ft from the throwing line. The distance the grenade landed from the pin was measured and recorded. In the kneeling throwing position, mean throwing accuracy ranged from 7.08 ft in the baseline condition to 11.83 ft in the dominant arm impairment condition. Although these were the means, minimum throwing accuracy was 5 inches and maximum throwing accuracy was 42.42 ft, which is quite a large variance in distance. The standing position revealed a mean throwing accuracy of 6.55 ft for the baseline condition to 9.28 ft for the dominant hand impairment condition. Again, the minimum throwing accuracy was 1 inch and the maximum was 23 ft. Lastly, mean throwing accuracy for the grenade throw in the supine position ranged from 7.65 ft in the dominant arm impairment condition to 8.82 ft in the nondominant arm condition. Similar to the other 2 throwing positions, minimum accuracy throw distance was 11 inches while the maximum accuracy throw distance was 31.25 ft. Nevertheless, no main effect or interaction was evident.

10.1.3 The Effect of Physical Impairment on Grenade Throw Timing Performance

Grenade throw timing was analyzed separately according to each throwing position. Timing performance measures were also broken down into 3 segments: 1) time to pull grenade from pouch, 2) time to pull pin, and 3) time to throw grenade.

A main effect of physical impairment condition ($F[4, 191] = 3.75$, $p = 0.006$) was found relative to pull from pouch time for the standing position. Post hoc Tukey' HSD analyses revealed a significant difference between only one of the physical impairment conditions (Fig. 9). As is apparent in the graph, there was a significant difference between the baseline and impairment of the dominant arm. It is understandable that impairment of the dominant arm would make it much more difficult to pull a grenade from a pouch. It is interesting that the impairment of the dominant arm does not take a significantly longer time to pull the grenade from the pouch than during impairment of the nondominant arm.

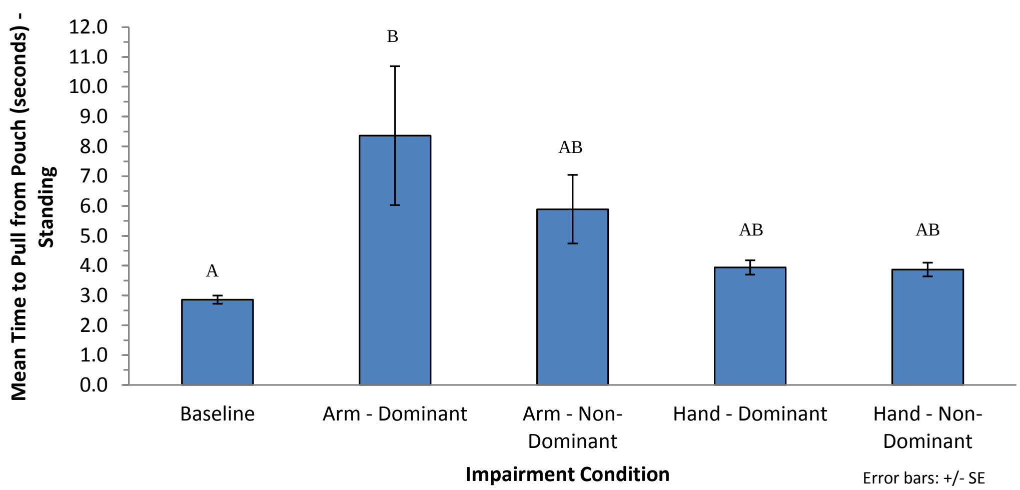


Fig. 9 The effect of physical impairment on mean time to pull from pouch from the standing position. Like letters indicate that there is no significant difference.

A main effect of physical impairment condition ($F[4,191] = 8.33$, $p = 0.0$) was found relative to pull pin time from the standing position. Post hoc Tukey HSD analyses revealed significant differences between some of the physical impairment conditions (Fig. 10).

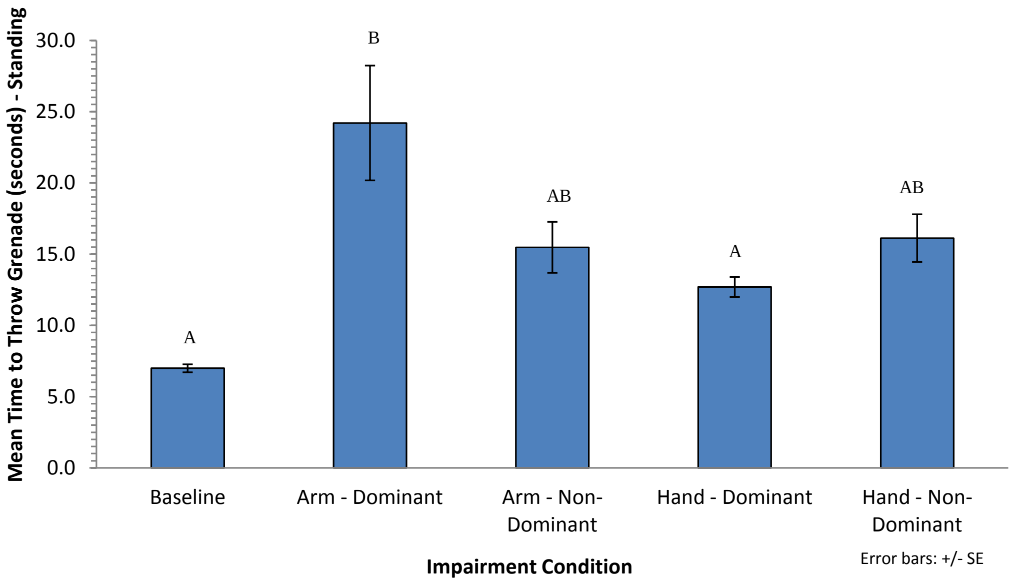


Fig. 10 The effect of physical impairment on mean time to pull pin from the standing position. Like letters indicate that there is no significant difference.

A significant difference occurred between the baseline and the dominant arm. Significant differences were also revealed between the dominant hand and the dominant arm. From these results it is apparent that impairment of the dominant arm during the pull-pin task results in a longer time to complete the task than when in any other impairment condition with the exception of the nondominant hand and nondominant arm conditions. When the dominant arm is impaired, the participant now holds the grenade in the nondominant hand. Consequently, the nondominant hand is now not available to pull the pin. This results in elevated task times for the pull-pin task. Similarly, when the nondominant hand is impaired, the pull-pin task cannot be performed in the traditional manner. Even though the grenade is held in the dominant hand, the nondominant hand is no longer available for pulling the pin, thereby resulting in a longer time to complete this task.

In addition, a main effect of physical impairment condition ($F[4,191] = 9.16$, $p = 0.0$) was found relative to throw-grenade time from the standing position. Post hoc Tukey HSD analyses revealed significant differences between some of the physical impairment conditions (Fig. 11).

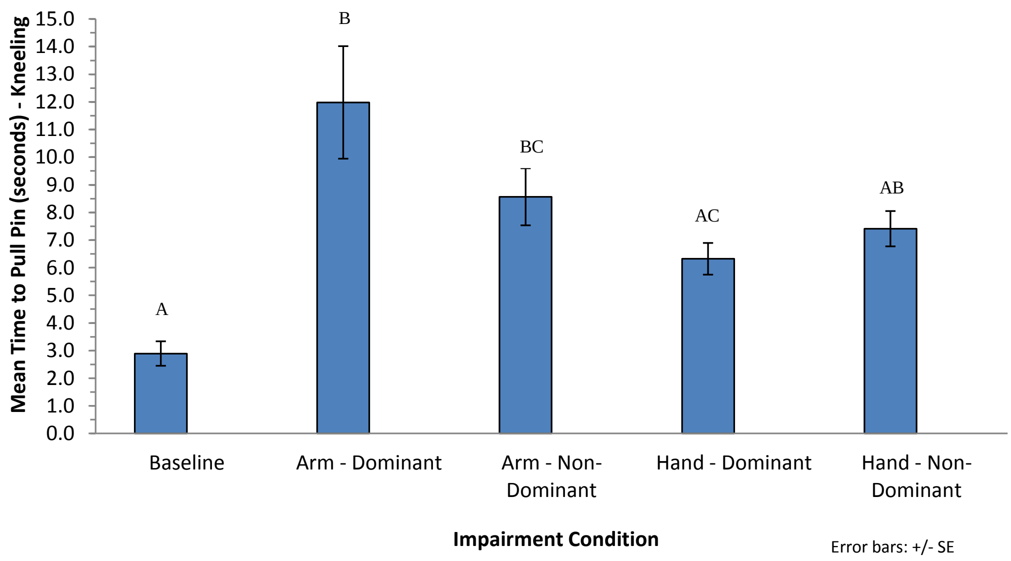


Fig. 11 The effect of physical impairment on mean time to throw the grenade from the standing position. Like letters indicate that there is no significant difference.

A significant difference was found between the baseline condition and the dominant arm. Impairment of the dominant arm also showed a significant difference with the dominant hand. It takes significantly longer to throw the grenade during impairment of the dominant arm than the baseline and dominant hand impairment conditions.

The same grenade throwing tasks from the kneeling position were analyzed. A significant main effect of physical impairment condition relative to pull-from-pouch time was revealed ($F[4,183] = 4.05$, $p = 0.004$). However, the post hoc Tukey HSD analyses showed no significant differences among the multiple comparisons.

A significant main effect of physical impairment condition relative to pull-pin time was revealed ($F[4,183] = 10.41$, $p = 0.0$). Post hoc Tukey HSD analyses revealed a significant main effect for impairment condition (Fig. 12). Significant differences were shown between the baseline and the dominant arm, and the nondominant arm. Similar to the pull-from-pouch task, no difference existed between the baseline and the dominant hand condition. A significant difference was revealed between the baseline and the dominant arm and the dominant hand.

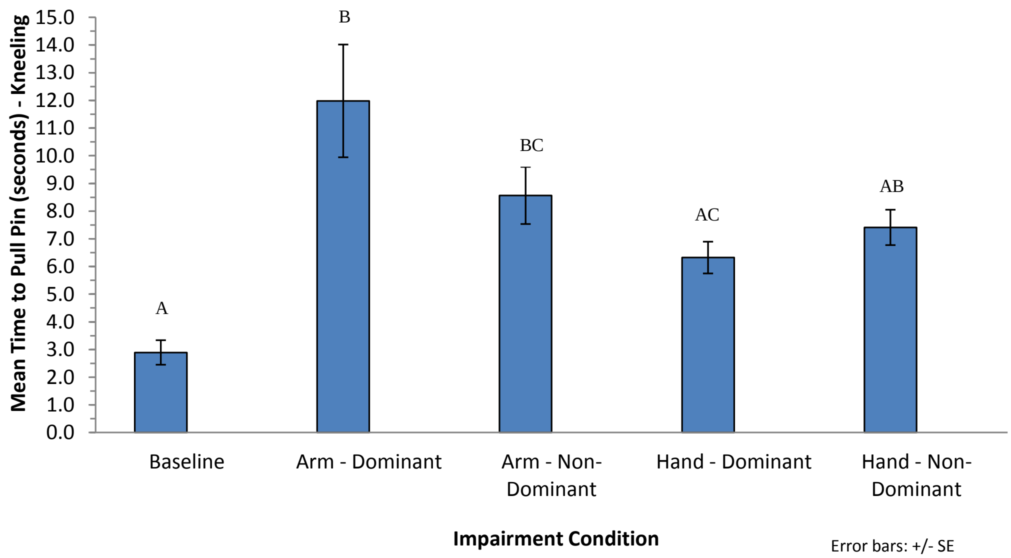


Fig. 12 The effect of physical impairment on mean time to pull pin from the kneeling position. Like letters indicate that there is no significant difference.

A significant main effect of physical impairment condition relative to throw-grenade time was also revealed (F[4,191] = 6.30, p = 0.0). Post hoc Tukey HSD analyses revealed a significant main effect for impairment condition (Fig. 13). Significant differences were revealed between the baseline and both the dominant arm and nondominant arm.

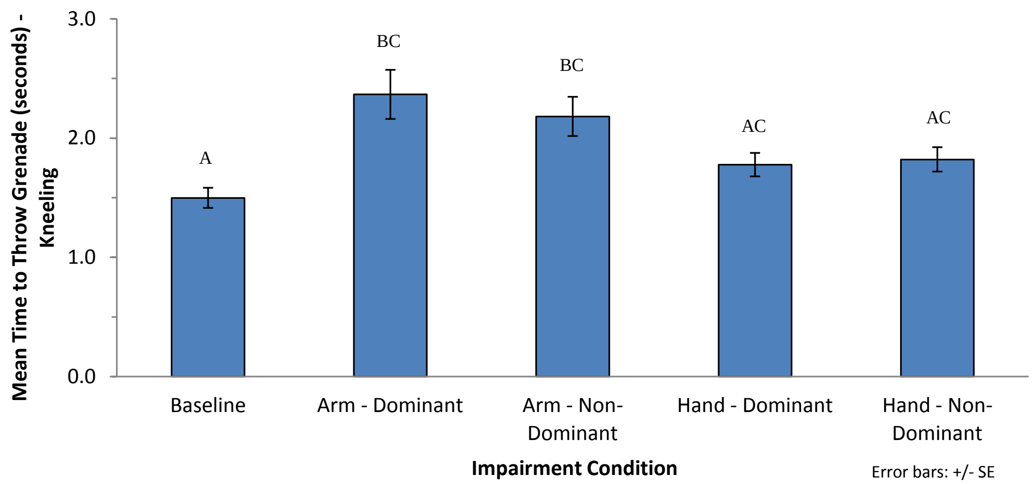


Fig. 13 The effect of physical impairment on mean time to throw grenade from the kneeling position. Like letters indicate that there is no significant difference.

Lastly, the 3 grenade tasks performed from the supine position were analyzed. There were no significant main effects of physical impairment condition relative to pull-pouch time (F[4,191] = 2.83, p = 0.026).

A significant main effect of physical impairment was shown relative to pull pin time (F[4,191] = 4.13, p = 0.003). Post hoc Tukey HSD analyses showed that significant differences occurred between the baseline and dominant hand condition (Fig. 14). It is apparent that pulling the pin from the grenade during the supine condition takes significantly longer during dominant hand impairment than during the baseline condition.

The effect of physical impairment relative to throw-grenade time in the supine condition did not reveal any significant main effects (F[4,191] = 2.88, p = 0.024).

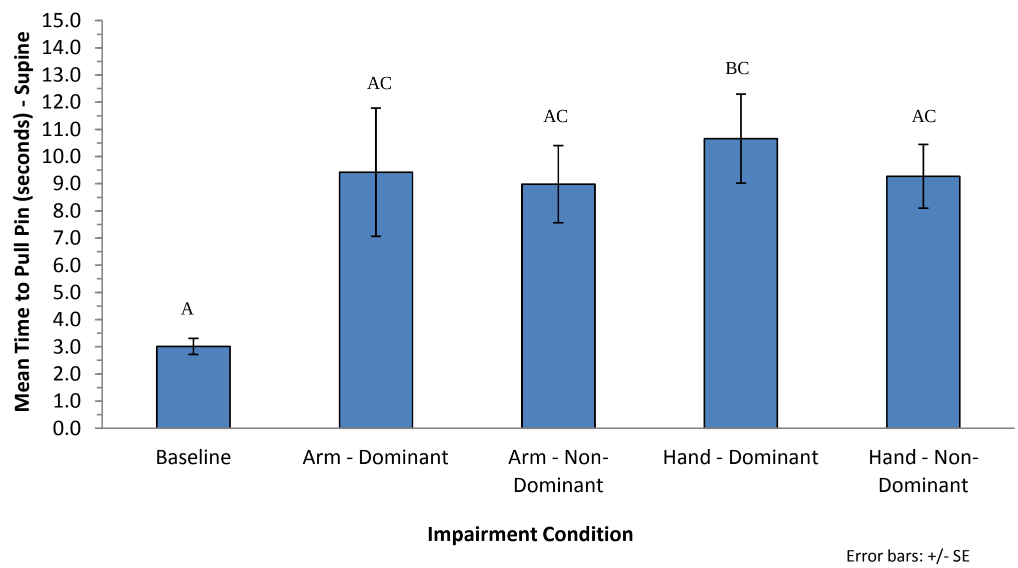


Fig. 14 The effect of physical impairment on mean time to pull pin from the supine position. Like letters indicate that there is no significant difference.

10.2 Weapon Loading Performance Data

Weapon loading timing, starting both with a loaded weapon and an unloaded weapon, were analyzed separately. Timing performance measures were broken down into segments. For the task starting with a loaded weapon, task segments were 1) time to drop magazine, 2) time to get new magazine, 3) time to load magazine, 4) time to release bolt, and 5) time to aim and pull the trigger. For the task starting with an unloaded weapon, task segments were 1) time to get new magazine from ammo pouch, 2) time to load magazine, 3) time to chamber a round, and 4) time to aim and pull the trigger.

10.2.1 The Effect of Physical Impairment on Reloading a Loaded Weapon

Main effects due to physical impairment condition were found relative to some of the task segments involved in loading the weapon. A main effect of physical impairment condition ($F[4, 45] = 7.141$, $p = 0.0$) was found relative to the time to drop magazine. Post hoc Tukey HSD analyses revealed significant differences between some of the physical impairment conditions (Fig. 15). Significant differences were revealed between both the baseline and the dominant arm and dominant hand condition. It took significantly longer to drop the magazine during impairment of the dominant arm or dominant hand than when there was no impairment.

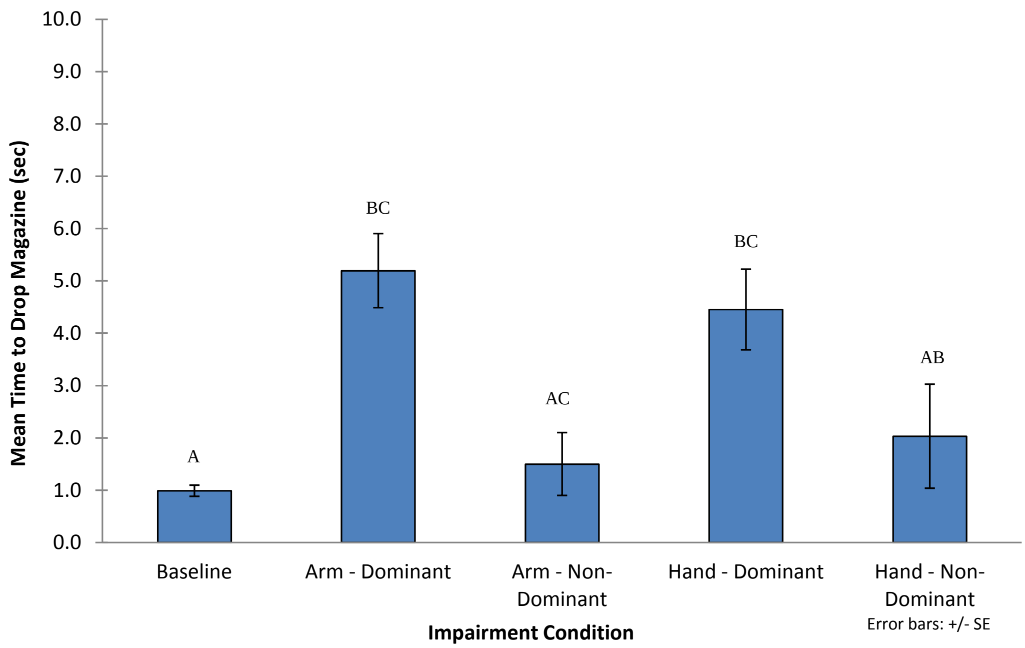


Fig. 15 The effect of physical impairment on mean time to drop magazine. Like letters indicate that there is no significant difference.

There were no effects of physical impairment condition ($F[4, 45] = 2.63$, $p = 0.046$) found relative to time to get a new magazine.

The task time to load a new magazine exhibited a main effect for physical impairment condition ($F[4,45] = 6.35$, $p = 0.0$). Post hoc Tukey HSD analysis showed a significant difference between the baseline and the dominant hand and the dominant arm conditions (Fig. 16). Loading a new magazine with the dominant hand or dominant arm impaired took significantly longer compared with the baseline.

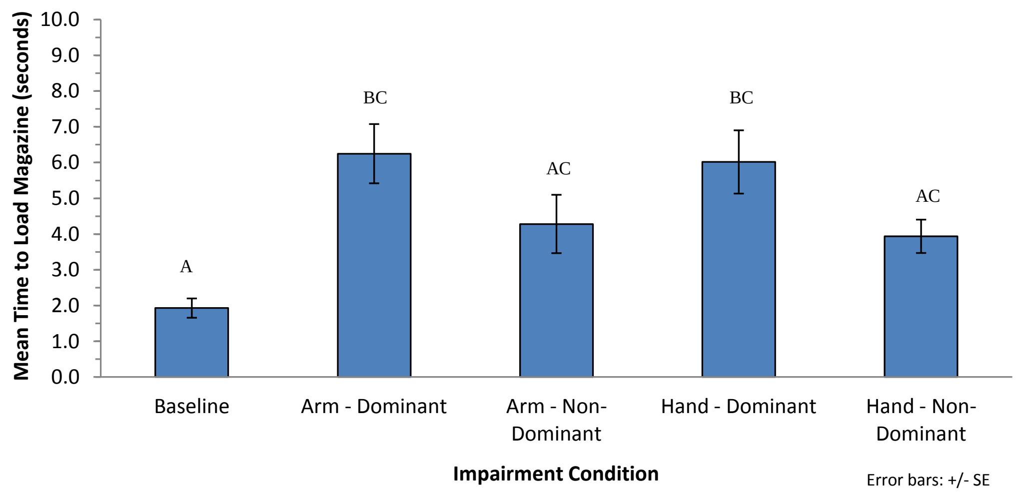


Fig. 16 The effect of physical impairment on mean time to load a new magazine. Like letters indicate that there is no significant difference.

A main effect for physical impairment was also found relative to the time to release the bolt ($F[4,45] = 4.38$, $p = 0.004$). Post hoc Tukey HSD analyses revealed a significant difference between the baseline with no impairment and impairment of the nondominant arm (Fig. 17). For this task, it took longer to release the bolt during impairment of the nondominant arm than no impairment at all.

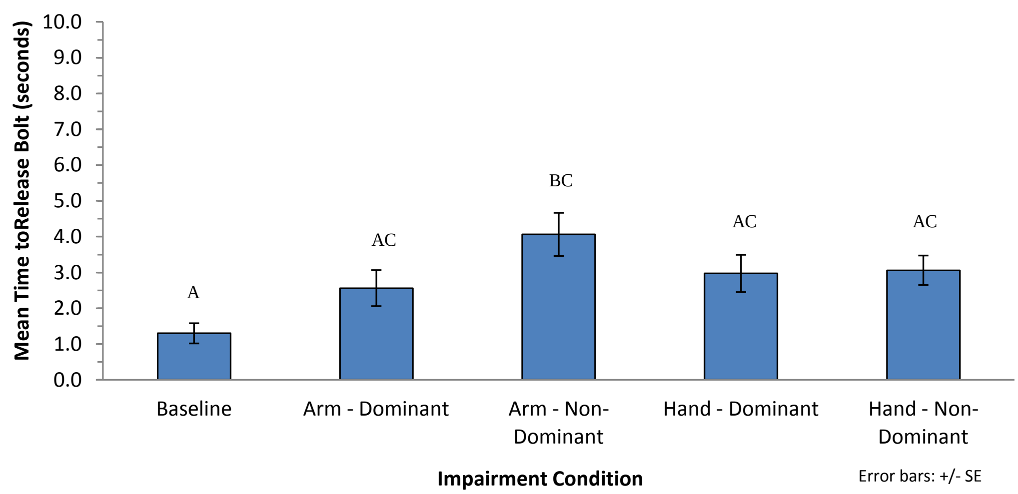


Fig. 17 The effect of physical impairment on mean time to release the bolt. Like letters indicate that there is no significant difference.

The final task in this sequence, the time to aim and pull the trigger did not show any main effects for physical impairment ($F[4,45] = 3.56$, $p = 0.013$).

10.2.2 The Effect of Physical Impairment on Loading an Unloaded Weapon

A main effect due to physical impairment condition was found relative to only one task segment involved in loading an unloaded weapon, specifically time to load a magazine. A main effect of physical impairment ($F[4,45] = 5.85$, $p = 0.001$) was found relative to time to load magazine. Post hoc Tukey HSD analysis revealed significant differences between the baseline and the dominant hand condition and nondominant hand conditions (Fig. 18). It took significantly longer to load a magazine during dominant hand and nondominant hand impairment compared with the baseline.

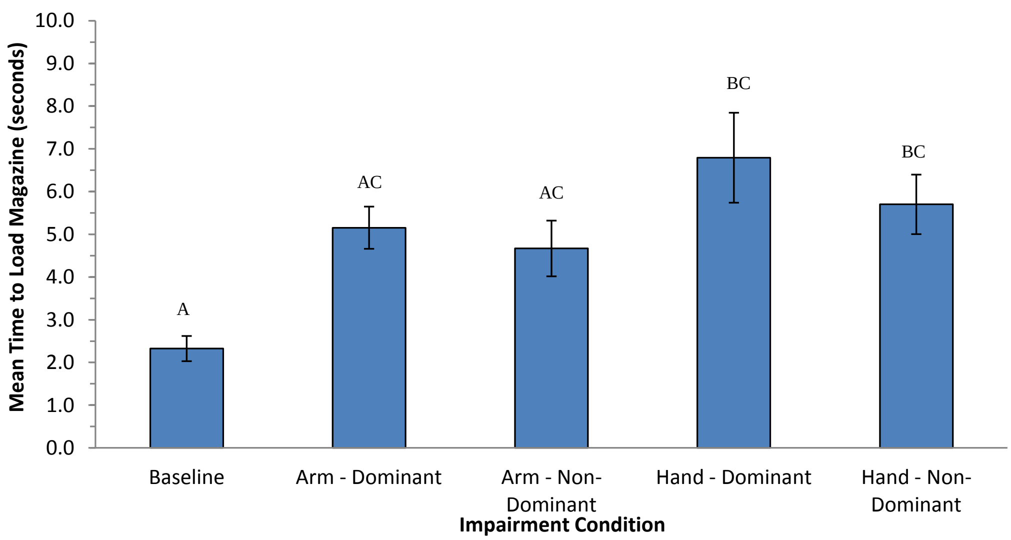


Fig. 18 The effect of physical impairment on mean time to load a magazine. Like letters indicate that there is no significant difference.

10.3 Subjective Data

After completing the grenade throw and the weapon loading tasks for each experimental condition, participants completed a post-experiment questionnaire included in Appendixes B and C. For the grenade throw task, the questionnaire prompted test participants to rate their ability to 1) control the throw, 2) pull the pin, 3) acquire a comfortable position, and 4) maintain stability in the hand. For the weapon loading tasks, starting with a loaded weapon, the questionnaire prompted test participants to rate their ability to 1) control the weapon, 2) drop the magazine, 3) pull the magazine from ammo pouch, 4) load the magazine into the weapon, 5) push bolt release, and 6) aim and pull trigger. Starting with an unloaded weapon, the questionnaire prompted test participants to rate their ability to 1) control the weapon, 2) load magazine from ammo pouch, 3) chamber a round and put selector

on semiautomatic, and 4) aim and pull the trigger. Ratings were recorded using a 7-point Likert scale that ranged from 1 (very bad) to 7 (very good), shown in Table 4. Results are summarized graphically, across experimental participants, in Figs. 19–31. The results here are against each treatment effect and not also against the baseline condition. In each of these subjective ratings, the baseline condition was always rated higher than any of the impairment conditions. Therefore, in the discussion of these ratings, the focus will be on the comparison of ratings between the impairment conditions only. When averaging ratings, if 3.0 equals "slightly bad", so does a rating of 3.1–3.4. If the average is 3.5–3.9, then for reporting purposes this is rounded up to the next rating point, "neutral".

Table 4 The 7-point Likert rating scale

1	2	3	4	5	6	7
Very bad	Moderately bad	Slightly bad	Neutral	Slightly good	Moderately good	Very good

The ability of participants to control the grenade throw was reported lowest when the dominant hand and dominant arm were impaired. This was true regardless of whether they were in the standing, kneeling, or lying prone position (Fig. 19).
The ability of participants to pull the pin was reported on average to be lowest when the dominant arm was impaired (Fig. 20). Although each impairment condition contributed to perceived difficulty in pulling the pin, participants rated the task as most difficult when they were unable to use the dominant arm.

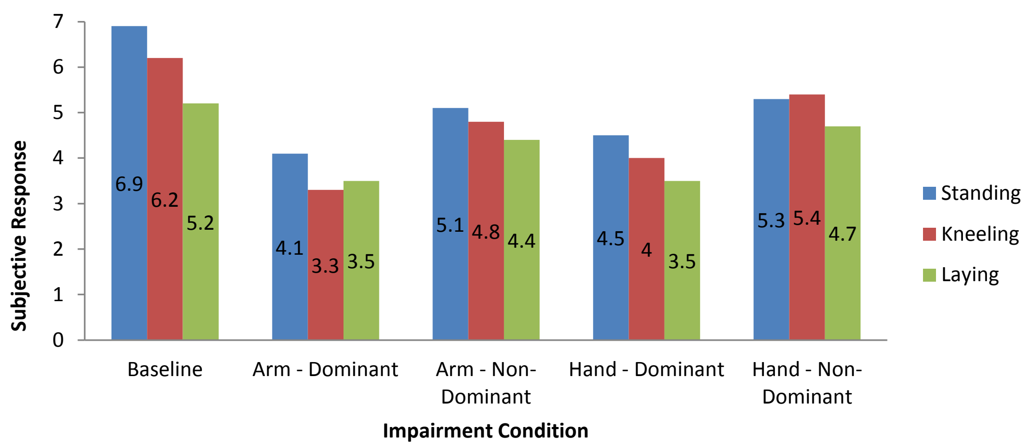


Fig. 19 Rating of ability to control the throw of the grenade by impairment condition in standing, kneeling, and supine positions

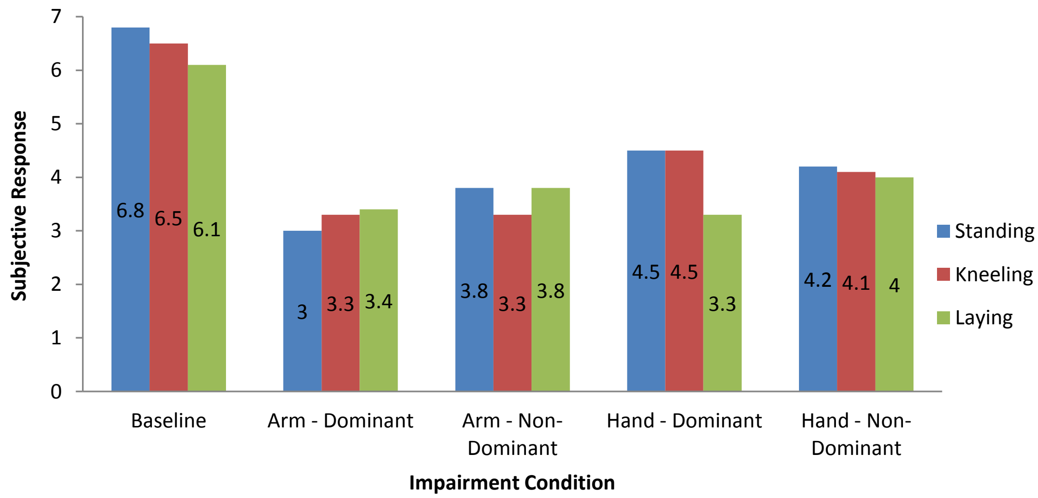


Fig. 20 Rating of ability to pull the pin by impairment condition in standing, kneeling, and supine positions

Ratings for maintaining a comfortable throwing position were slightly lower when the dominant hand and dominant arm were impaired (Fig. 21). It is evident that when participants are forced to rely on the nondominant side, they perceive the task to be more difficult.

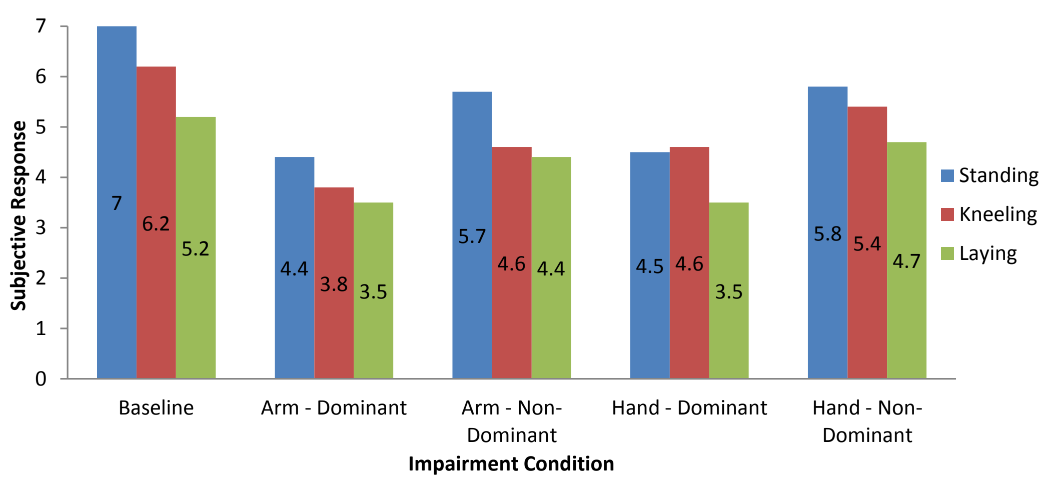


Fig. 21 Rating of ability to maintain a comfortable throwing position by impairment condition in standing, kneeling, and supine positions

Lastly, the ability of participants to maintain stability of the grenade in the hand is fairly consistent across the impairment conditions (Fig. 22). The impairment of the dominant hand and arm show only a slightly lower rating than the other impairment conditions for the ability to maintain stability.

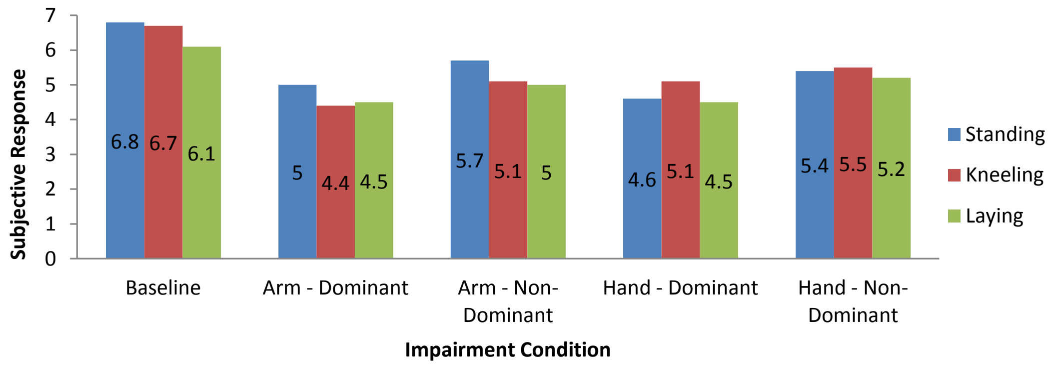


Fig. 22 Rating of ability to maintain stability of the grenade in hand by impairment condition in standing, kneeling, and supine positions

Subjective ratings were also obtained for the weapon loading task. Starting with a loaded weapon, participants rated the ability to control the weapon during the task (Fig. 23). Participants rated impairment of the dominant hand and arm as slightly bad to neutral in the task of controlling the weapon. Similarly, the participants also reported difficulty, again slightly bad to neutral, in dropping the magazine when the dominant hand or dominant arm was impaired (Fig. 24).

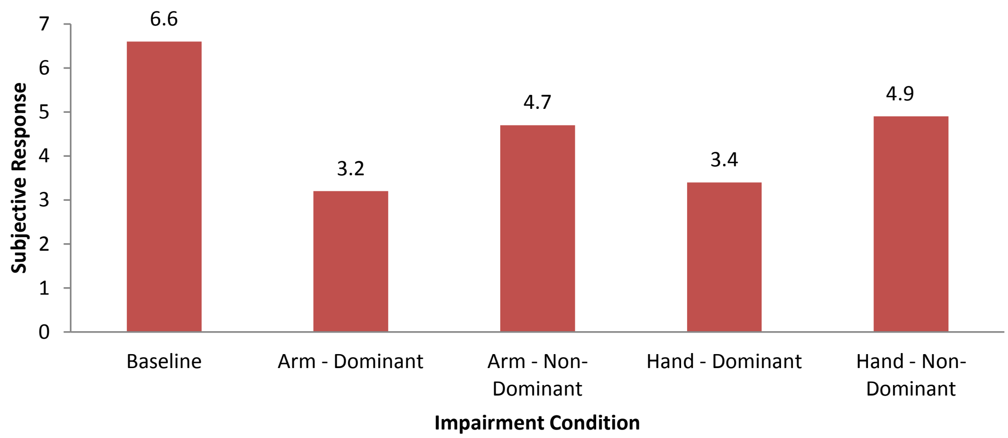


Fig. 23 Rating of the ability to control the weapon during the loading task

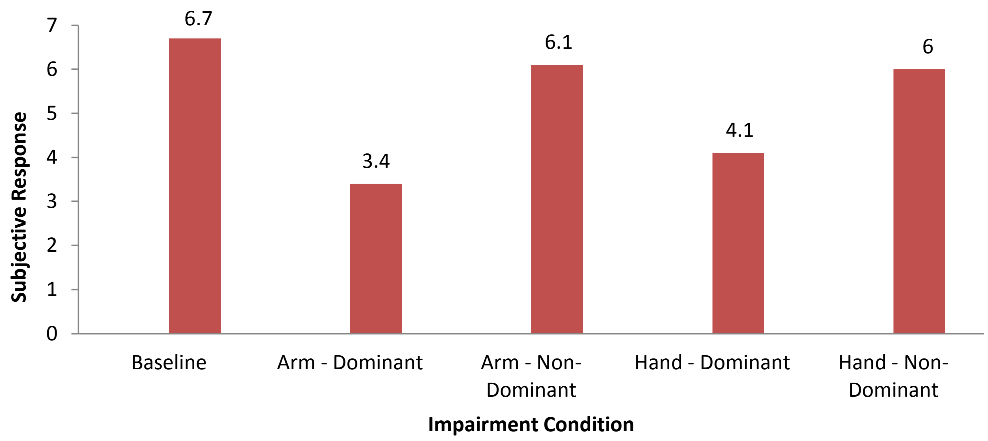


Fig. 24 Rating of ability to drop the magazine by impairment condition during the loading task

Participants rated the ability to pull the magazine from the pouch only slightly lower (slightly good to moderately good) than the other conditions when the dominant hand or arm was impaired (Fig. 25). This task did not seem to present as much difficulty as other tasks even when the dominant side was impaired.

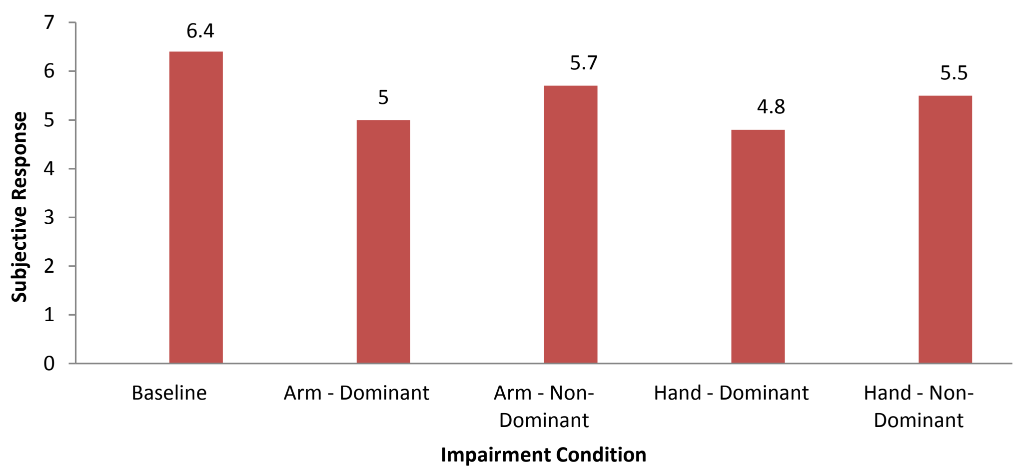


Fig. 25 Rating of ability to pull the magazine from the pouch by impairment condition during the loading task

Participants rated the ability to release the bolt as neutral to slightly good (Fig. 26). Although the performance measures for releasing the bolt suggest that the task was more difficult under impairment than the baseline condition, the ratings for this task suggest that participants perceived that their ability to release the bolt, even during impairment, was good.

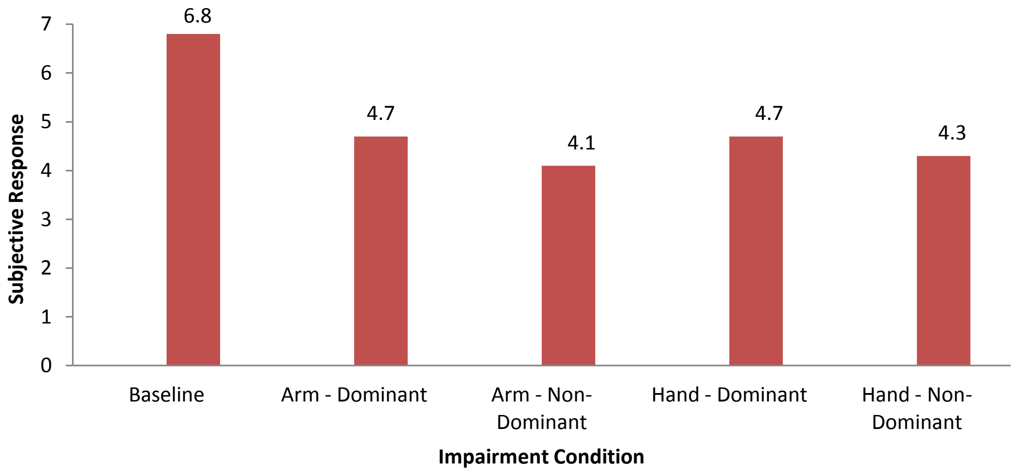


Fig. 26 Rating of ability to release the bolt by impairment condition during the loading task

Lastly, the ability to aim and pull the trigger while under impairment was rated lowest for the impairment of the dominant arm or dominant hand condition (Fig. 27). Participants rated their ability to perform this task from neutral to moderately good.

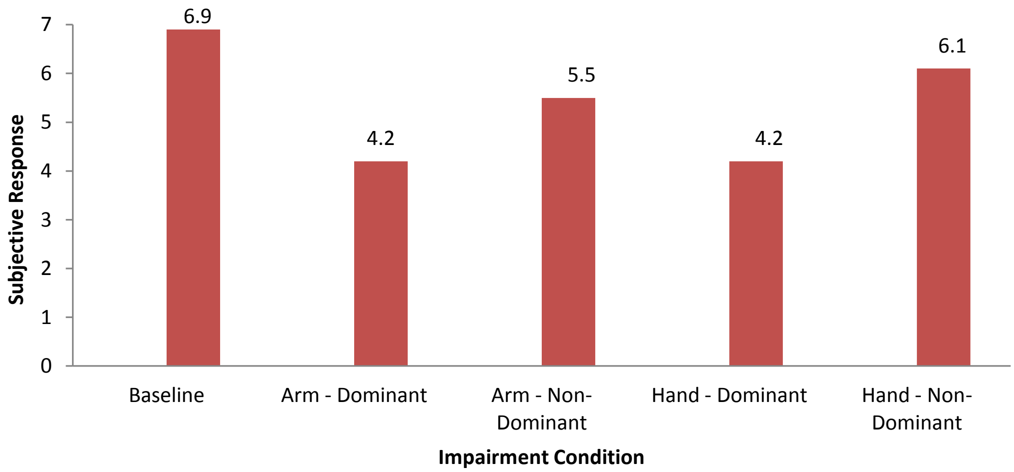


Fig. 27 Rating of the ability to aim and pull trigger by impairment condition during the loading task

Starting with an unloaded weapon, participants rated the ability to control the weapon (Fig. 28). Participants rated controlling the weapon for this task as slightly bad to neutral when the dominant hand or the dominant arm was impaired. When the nondominant arm or hand was impaired, ratings improved to slightly good.

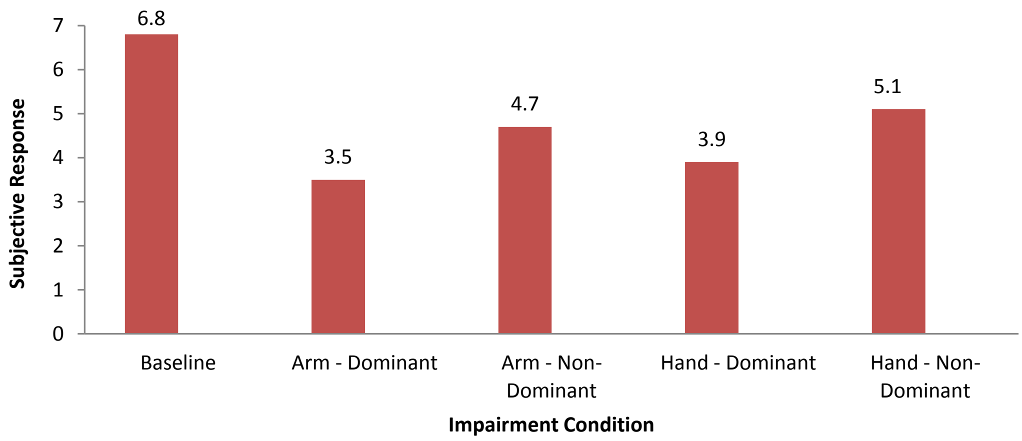


Fig. 28 Rating of the ability to control the weapon by impairment condition during the loading task, starting with an unloaded weapon

Participants also rated the ability to load a magazine (Fig. 29). All of the impairment conditions were rated as having some difficulty in loading a magazine, but the lowest ratings surfaced when the dominant hand, dominant arm or nondominant arm was impaired.

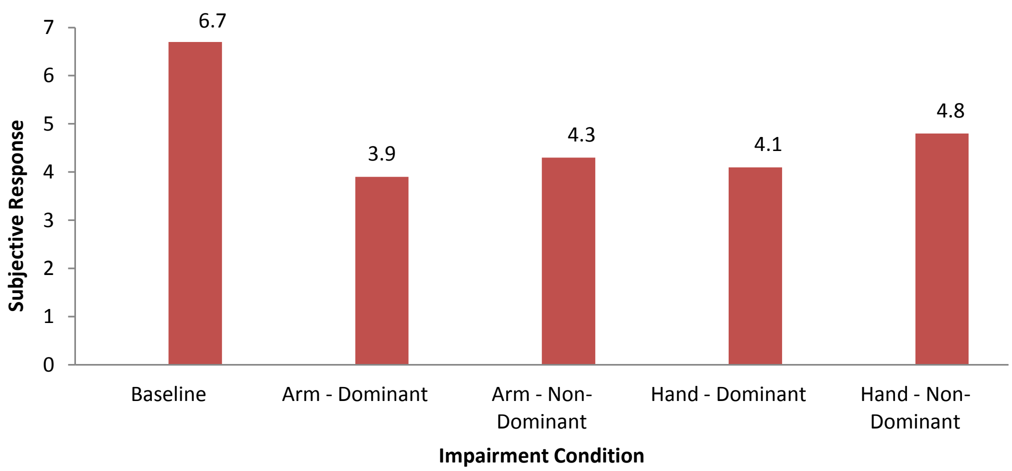


Fig. 29 Rating of the ability to load the magazine by impairment condition during the loading task, starting with an unloaded weapon

Participants rated the ability to chamber a round and place weapon on semiautomatic as slightly bad when the dominant arm was impaired (Fig. 30). Ratings increased slightly to neutral when the nondominant hand, nondominant arm, or dominant hand was impaired.

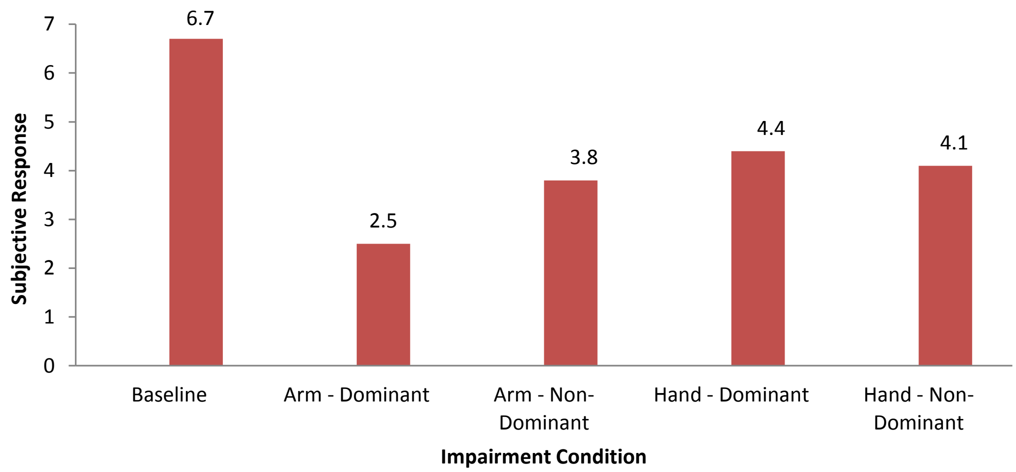


Fig. 30 Rating of the ability to chamber a round and place weapon on semiautomatic by impairment condition during the loading task, starting with an unloaded weapon

Finally, participants rated the ability to aim and pull the trigger (Fig. 31). Ratings were neutral to slightly good for conditions in which the dominant hand or arm was impaired. Ratings increased to moderately and very good when the nondominant side was impaired or during baseline when there was no impairment at all.

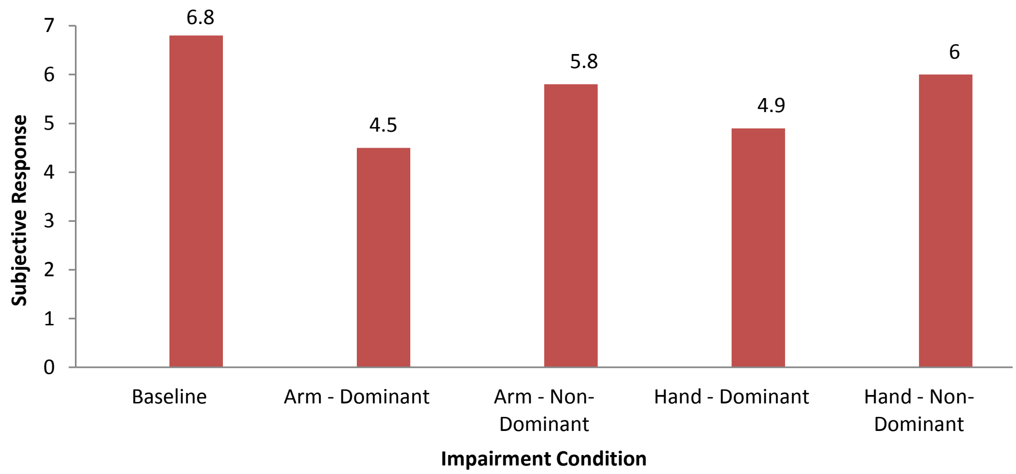


Fig. 31 Rating of the ability to aim and pull trigger by impairment condition during the loading task, starting with an unloaded weapon

11. Discussion

An impaired limb significantly affects the ability to throw a grenade and load a weapon. Significant differences in mean grenade throwing distance were found relative to impairment condition. In the standing position, several impairment conditions were significantly different from each other. There was no significant difference between the baseline and nondominant hand condition. This was because

in these conditions, participants threw the grenade with the same hand. There was also no significant difference between impairment of the dominant hand and the dominant arm conditions. It appeared to be more difficult to throw a grenade from the dominant side when the nondominant hand was impaired than the baseline condition with no impairment.

In the kneeling position, impairment of the dominant hand and dominant arm caused participants to throw the grenade for shorter throwing distances. However, the baseline, nondominant arm, and nondominant hand impairment conditions were all statistically similar for throw distance. Participants threw significantly farther when the nondominant hand or arm was impaired.

In the supine position, participants' throwing distances were even shorter than reported for the kneeling position. Again, impairment of the dominant hand and dominant arm caused participants to exhibit shorter throwing distances. They were significantly different than the baseline condition. The baseline, nondominant arm, and nondominant hand conditions were all statistically similar for throw distance. At this position, impairment of the dominant arm or dominant hand revealed significantly shorter throws.

Significant differences were found in mean time to complete the individual subtasks when throwing a grenade relative to impairment condition. When in the standing position, significant differences were found for pull-from-pouch time relative to impairment condition. It took significantly longer to pull the grenade from the pouch when the dominant arm was impaired than during the baseline condition with no impairment. The impairment of the dominant and nondominant hand was surprisingly more similar to the baseline condition. If one or the other hands were impaired, participants were able to easily switch to the other hand to pull the grenade from the pouch. We do not understand why the impairment of the dominant arm increased pull from pouch time so significantly. One might expect that they could easily just pull with the nondominant hand but this did not seem to be the case. Impairment of the entire dominant arm caused much difficulty in this task.

From the standing position, significant differences were revealed for pin-pull time between the baseline and dominant arm impairment. It took significantly longer to pull the pin from the standing position when the dominant arm was impaired than the unimpaired baseline condition. In this task, the nondominant hand is used to pull the pin. Under dominant arm impairment, this is no longer possible. Often during the experimentation, participants under impairment would use parts of the weapon to wrap the pull-pin ring around and assist in pulling the pin. When the dominant arm was impaired, the participant now had to hold the grenade in the nondominant hand and attempt to pull the pin using whatever means possible.

When the dominant arm was impaired, the weapon was not easily stabilized and therefore created more difficulty in pulling the pin. It took significantly longer to pull the pin when the entire dominant arm was impaired rather than only the dominant hand. It was observed during data collection that when only the dominant hand was impaired, the participant still used other parts of the arm to stabilize the weapon for the pull-pin task.

Significant differences were found for grenade throw time from the standing position relative to physical impairment condition. The dominant arm condition took significantly longer to throw than the unimpaired baseline condition. It was expected that the impaired dominant arm condition would reveal this result, as it takes the whole arm to make a throw.

The kneeling position for these same 3 subtasks was studied. A main effect was found for pull-from-pouch time relative to physical impairment condition. However, there were no significant differences among the multiple comparisons. Also, time to pull the pin showed significant differences relative to physical impairment condition. It took significantly longer to pull the pin during impairment of the dominant arm and nondominant arm when compared with the baseline. Interestingly, again the impairment of the dominant hand was similar in pull-pin time to the baseline. It also takes significantly longer to pull the pin when the dominant arm is impaired compared with either the dominant hand or baseline conditions. The dominant arm appears to be instrumental in stabilizing the weapon so the pin can be pulled using the nondominant hand.

Significant differences were found for grenade throw time from the kneeling position relative to physical impairment condition. Grenade throw time for the dominant arm and nondominant arm condition were significantly slower than the baseline condition. Again, the impairment of the dominant and nondominant arm seems to stand out as the impairment conditions that statistically differentiate the rest in terms of effect on the throwing task.

Lastly, only one of the grenade throw subtasks from the supine position showed a significant main effect relative to physical impairment condition. The pull-from-pouch time revealed no significant differences relative to physical impairment condition. Pull-pin time from the supine position showed significant differences between the baseline and the dominant hand condition. It took significantly longer to pull the pin from the dominant hand impairment condition compared with the baseline. This seemed to be one of the most difficult tasks to perform, especially in the supine position. Pull-pin times across all the other impairment conditions were statistically similar. Time to throw a grenade from the supine position relative to impairment condition revealed no significant differences.

Weapon loading performance was also examined relative to physical impairment. Specifically, the effects of physical impairment on loading a loaded weapon were examined. Five individual subtasks were analyzed to understand the effect of impairment. The first task, time to drop magazine, showed that it took significantly longer to drop the magazine during impairment of the dominant arm or impairment of the dominant hand compared with the baseline condition. In most cases, the dominant hand is used to drop the magazine, which is why task time increases when the dominant hand or arm is impaired.

Significant differences were found for time to load a new magazine relative to physical impairment condition. Impairment of the dominant hand and dominant arm conditions required a significantly longer time to load a new magazine when compared with the baseline condition. Switching over to the nondominant side for this particular subtask was difficult regardless of whether it was just the hand or entire arm that was impaired.

Time to release the bolt also showed an effect of impairment. For this subtask, it took significantly longer to release the bolt when the nondominant arm was impaired when compared with the baseline with no impairment. Since the bolt is normally released using the nondominant hand, this would make it difficult because the nondominant arm and hand is no longer able to be used for this task, thus the significant increase in time.

Similarly, the effects of loading an unloaded weapon were also examined. The only task that revealed a significant main effect of physical impairment was time to load a magazine, which showed that it took significantly longer to load a magazine during impairment of the dominant hand or nondominant hand condition compared with the baseline. Participants struggled under these conditions to load the magazine. When participants had to switch to the other hand to conduct this task, task time increased, as would be expected. Furthermore, when the nondominant hand was impaired, this only left the arm itself to stabilize the weapon for loading with the dominant hand.

Our subjective results support the empirical findings for both the grenade throw and weapon loading tasks. The ability to control the grenade, pull the pin, maintain a comfortable throwing position, and maintain stability of the grenade in the hand were all negatively affected when the dominant side was impaired.

Similarly, starting either with a loaded or unloaded weapon, participants reported that the ability to control the weapon and drop the magazine during impairment of the dominant side caused difficulty. The ability to pull the magazine from the pouch and the ability to release the bolt did not present as much difficulty when the dominant side was impaired. Participants were able to accommodate using only the

nondominant side. Participants rated the ability to chamber a round and place the weapon on semiautomatic as difficult when the dominant arm was impaired. The ability to aim and pull the trigger did not seem to cause difficulty during impairment of either side.

12. Conclusions

From the standing position, impairment of the dominant arm and dominant hand showed a significant effect on throwing distance compared with the baseline. Although the effect of dominant arm and hand impairment was expected, this was somewhat because of the need to switch to the nondominant side for the completion of this task. Similarly, both the kneeling and supine positions revealed difficulty in throwing during dominant arm and hand impairment. Likewise, in these throwing positions, the need to switch to the nondominant side caused significant differences in distance thrown.

The time to complete the individual subtasks of the grenade throw were also affected. There was little consistency among results: Each subtask was affected by impairment but also by position. For the standing task, each of the subtasks, i.e., pull-from-pouch, pull-pin, and throw grenade, showed significant higher completion times during dominant arm impairment compared with the baseline. It was difficult for Soldiers to switch over to the nondominant side when performing each of these tasks.

In the kneeling position, although the increased time was not as pronounced as in the standing position, the impairment of the dominant arm still showed the most dramatic effect on the time to complete each of the 3 subtasks.

The supine position revealed somewhat different results compared with the kneeling and standing positions. The pull-from-pouch time revealed no significant differences relative to impairment condition. The following pin-pull task would normally be conducted using the nondominant hand. Participants might have been thinking through the process, thereby increasing pull-from-pouch time. Although pull-pin task times were elevated, only the dominant hand condition revealed a significantly higher task time compared with the baseline. This is normally the hand that would hold the grenade while the pin is pulled with the other hand. Since this was not possible in this condition, Soldiers had to determine a way to secure the grenade while pulling the pin with the nondominant hand. Throwing the grenade from the supine position did not reveal any significant differences in task time relevant to condition.

The effects of physical impairment were apparent on the time to complete the subtasks involved in loading a loaded weapon. In dropping the magazine, both the dominant arm and dominant hand condition revealed significantly slower times relative to the baseline condition. Since the dominant hand is predominantly used for this task, this was not a surprise. Time to get a new magazine showed no significant differences. Impairment of the dominant hand and dominant arm revealed significantly higher completion times for loading a new magazine compared with the baseline. Similar to dropping the magazine, the dominant arm and hand is used for weapon loading. Time to release bolt showed a significantly higher task completion time for the nondominant arm impairment condition compared with the baseline. Since this task it usually performed with the nondominant hand, there is difficulty having to switch to the dominant side to perform this task. The task of aiming and pulling the trigger did not reveal any significant effects. Overall, the dominant arm and dominant hand impairment conditions stand out as having the most effect on performance.

The effects of physical impairment on the time to complete the subtasks involved in loading an unloaded weapon were apparent for only one task—time to load a magazine. Loading a magazine revealed higher task completion times under dominant hand and nondominant hand conditions compared with the baseline. There is, then, no straightforward answer to physical impairment and its effect on grenade throw and weapon loading. The grenade task and weapon loading task are comprised of completely different subtasks and requirements, which accounts for the widely varied results. Each element of each task must be considered independently.

These findings will be incorporated into the ARL/Survivability and Lethality and Analysis Directorate's ORCA model. It is important that the manner in which impairment was simulated was purely physical. There was no emotional distress of being injured, which could be a confounding variable. Consequently, this research will aid in validation of elemental capabilities required for each of these tasks and the threshold at which they can no longer be successfully executed based solely on physical impairment.

13. Recommendation

It would be beneficial to include training under impairment in Soldier training. Training on each subtask, rather on the task as a whole, would be beneficial in improving performance. Conducting training while under similar conditions of impairment would give Soldiers the opportunity for to work through these possible situations while in a benign environment. Only through task exposure and practice will these impairments be overcome.

14. Reference

1. Swoboda J, Harper W, Morelli F, Wiley P. The effects of physical impairment on shooting performance. Aberdeen Proving Ground (MD): Army Research Laboratory (US); 2012. Report No.: ARL-TR-6102. Also available at: http://www.arl.army.mil/arlreports/2012/ARL-TR-6102.pdf.

Appendix A. Demographic Questionnaire

This appendix appears in its original form, without editorial change.

APPENDIX A
DEMOGRAPHIC QUESTIONNAIRE

Participant Number ________

Age_____ Gender ____ Rank______ Year and Month entered Military Service _____ / ____

Height ___ ft. ___ in. Weight _____lbs. Primary MOS______ Secondary MOS______

Job Title/Description: __________________Time in current job ________________

1. When was the last time you qualified with the M4 Carbine/M16 Rifle?

   Month ______ Year _____

2. What is your current level of qualification as rifleman?

   Marksman____ Sharpshooter ____ Expert ____

3. Have you qualified for the grenade throw?

   Yes____ No ____

4. Are you left-handed ____, right-handed ____ or ambidextrous____? (Check one)

5. Are you a left-handed ____or right-handed ____rifle shooter? (Check one)

6. Do you use your ____left eye or ____right eye to aim a weapon? (Check one)

7. Do you wear prescription glasses or contact lenses? Yes ___ No ___
   If yes, are you wearing them now? Yes_____ No______

8. Do you have any unusual difficulties seeing objects during daytime? Yes ___ No ___
   If yes, what difficulties do you experience?

Appendix B. Post-Grenade-Throw Questionnaire

This appendix appears in its original form, without editorial change.

POST-GRENADE THROW QUESTIONNAIRE

Test Participant number ______ Condition:________ Date:______

Please rate the following as it pertains to your experience with the experimental condition you just fired using the 7-point scale as shown below.

1	2	3	4	5	6	7	**N**
Very Bad	Moderately Bad	Slightly Bad	Neutral	Slightly Good	Moderately Good	Very Good	Could not Evaluate

	1	2	3	4	5	6	7	**N**
1. Ability to control your throw								
2. Ability to pull the pin								
3. Ability to attain a comfortable throwing position								
4. Stability of the grenade in your hand (Good stability would be if the grenade did not slip out of your hand, bad stability would be if the grenade slipped out of your hand)								

Appendix C. Post-Weapon-Loading Questionnaire

This appendix appears in its original form, without editorial change.

POST-WEAPON LOADING QUESTIONNAIRE

Test Participant number ______ Condition:________ Date:______

Starting with Loaded Weapon
Please rate the following as it pertains to your experience with the experimental condition you just fired using the 7-point scale as shown below.

1	2	3	4	5	6	7	**N**
Very Bad	Moderately Bad	Slightly Bad	Neutral	Slightly Good	Moderately Good	Very Good	Could not Evaluate

	1	2	3	4	5	6	7	**N**
1. Ability to control the weapon								
2. Ability to drop the magazine								
3. Ability to pull magazine from ammo pouch								
4. Ability to load the magazine into weapon								
5. Ability to push bolt release								
6. Ability to aim and pull trigger								

Please provide any additional comments on the condition in which you just participated:

Starting with Unloaded Weapon
Please rate the following as it pertains to your experience with the experimental condition you just fired using the 7-point scale as shown below.

1	2	3	4	5	6	7	**N**
Very Bad	Moderately Bad	Slightly Bad	Neutral	Slightly Good	Moderately Good	Very Good	Could not Evaluate

	1	2	3	4	5	6	7	**N**
1. Ability to control the weapon								
2. Ability to load magazine from ammo pouch								
3. Ability to chamber a round and put selector on SA								
4. Ability to pull trigger								

Please provide any additional comments on the condition in which you just participated:

List of Symbols, Abbreviations, and Acronyms

ANOVA	analysis of variance
ARL	US Army Research Laboratory
HRED	Human Research and Engineering Directorate
JTAPIC	Joint Trauma Analysis and Prevention of Injury in Combat
ORCA	Operational Requirement-Based Casualty Assessment model
SPEAR	Soldier Performance and Equipment Advanced Research
V&V	verify and validate

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